

# The Exploration of Taxi System

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**Abstract.** Through the analysis of the population distribution of the city, we find the optimal number of cabs needed to serve Tompkins. Main hypothesis of the model is that the service desk is moving ahead, and not only the service object need to wait for service, service desk is also waiting for the customer. The total number of cabs needed to serve the Tompkins is 607. Then we find the price between each area. After that we build a price model between two regions, and get-set the distance equal charge and region. Furtherly, we calculate the mean value of  $\lambda$  and the mean square error and draw the waveform of. Finally, we get cents per each mile =244.7657.

## Introduction

Tompkins has nine landmarks and destinations. There is a significant portion of the population, especially lower incomes and temporary residents, relies on taxicabs.

We face mainly two problems:

Set up a model to obtain the number of cabs.

Get the cents per each mile and analysis the advantages and disadvantages of switching to meters

## Previous Research

Some models are applied the field of car rental research. The *Douglas* model[1] in the study of the domain of taxi occupies very important position. So far the conclusions of the model are used in the literature or improved on its basis.

## Assumptions

Passengers were distributed evenly in the city, and the passengers' individual differences can be neglected;

The operating cost of taxis in unit time is considered to be constant;

## Symbols, Terminology Definitions

### Symbols and Definitions

Table 1. Model parameters

Parameter	Meaning
$\lambda$	The floating population every minute
$\mu$	The time servicing one person
$s$	The number of taxis
$n$	The number of customers
$P$	The proportion of taking a taxi
$L_q$	The average queue length

## To predict the taxi number

**The Model of the First Topic.** The first solution of the number cabs is a statistical problem. We should through the demographic analysis of taking taxis to confirm the optimal number of the cabs. The Foundation of Model

Step 1: Collect the intensity of the trip

We think trip intensity have something to do with the geographical environment, the economy of the city itself and so on. By collating the data that we collected, we can get the intensity of the trip is  $Q = 3.0302$ .

Step 2: To obtain the floating population and the number of people who call taxis

By collating the data that we collected, we can get the resident population of Tompkins is about 100 thousand.

We calculated the floating population using:

$$R_f = R_r \times Q \quad (1)$$

According to the above formula, we can calculate the floating population as shown as Table 2.

Table 2. The distribution of landmark districts' floating population

Section number	Area A	Area B	Area C	Area D	Area E	AreaF	Area G	Area H	AreaI
$R_f$	15294	9628	10778	27820	23059	7298	99771	41682	57120

After take the proportion of taking taxis into consideration, we should amend the floating population

Then we will convert the daily floating population to every hour as the formula follow:

$$\lambda = \frac{R_f}{24 \times 60} \times P \quad (2)$$

Finally, we obtain the floating population every hour in table 3.

Table 3. The floating population every minute

Sectionnumber	Area A	Area B	Area C	Area D	Area E	AreaF	Area G	Area H	AreaI
$P$	0.46	0.60	0.47	0.53	0.48	0.54	0.63	0.44	0.50
$\lambda$	10.62	6.69	7.48	19.32	16.01	5.07	69.29	28.95	39.67

After above, we will use the data in table 3 to build model.

Step 3: Build Population OD distribution

We use the floating population build OD distribution. The “O” denotes the starting point and the “D” denotes the terminal point.

For example, from area A to area B, the floating population is 956.

Step4: The optimal prediction model of the number taxis——queuing model with multi-server [2].

When calculating the number of taxis, we should pay attention that the number of the taxis have nothing to do with the specific rate.

Then we need to establish a queuing model with multi-server ( $M / M / s / \infty$ )

Step 5: The two conditions of Queuing Model with multi-server

The average sojourn time

$$W_s = \frac{L_s}{\lambda} \quad (10)$$

The averagewaiting time

$$W_q = \frac{L_q}{\lambda} = W_s - \frac{1}{\mu} \quad (11)$$

In our model, objective function is minimal.

The first constraint condition is  $W_q \leq 15$ , and the other is  $\frac{W_s}{90\%} - \frac{1}{\mu} \leq 25$ .

Result & Analysis. Through the above queuing model, we use Lingo obtain the result as follows:

Table 4. The taxi demand per area

Section number	Area A	Area B	Area C	Area D	Area E	Area F	Area G	Area H	Area I
$n_i$	55	86	63	50	61	40	104	59	89

$$n = \sum_{i=1}^9 n_i = 607$$

In conclusion, the total number of cabs needed to serve the Tompkins is 607. By querying data, the number of car ownership is two cars for every one thousand people in the United States. According to the proportion, then the number of car ownership in Ithaca is among 500 ~ 700. So the calculation result is accurate and the model assumption is quite reasonable.

### Cents per mile

**Modeling process.** We can obtain the price list of each area by looking up information. Then, we can get cents per each mile.

Calculate the mean value of  $x$  and the mean square error and draw the map of  $x$ . Because the distribution of known that the deviations between the points is bigger, we will remove these points. Then we calculate the mean value and variance of  $x$ , and draw the distribution of  $x$  as follows:

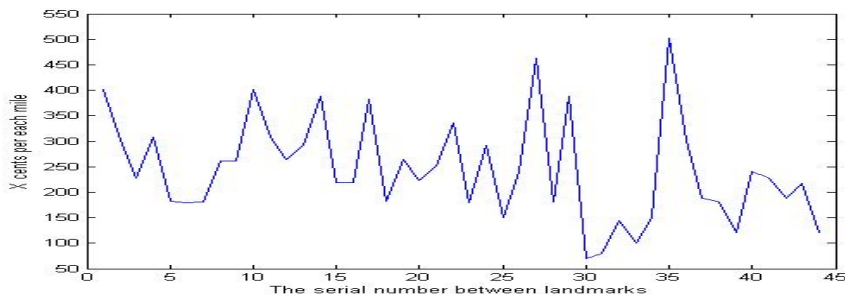


Figure 1.  $x$  distribution diagram after adjust

Mean-square deviation =  $9.9365e+03$ , average value = 244.7657  
 $x = 244.7657$

### Sensitivity analysis

Sensitivity analysis on model two:

In order to watch the trend clearly, we use the histogram to analysis.

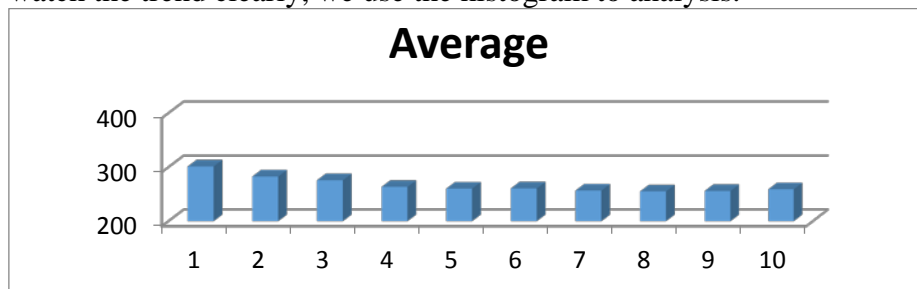


Figure 2. The average of each area

We can see from the average, when the calculation goes on the seventh time, the minimum average is 255.2353. But it is still a value greater than remove four points for the first time which the value is

244.7657. And through query data, the current value of  $x$  is 220 in the United States, that is, the error is 11.2571%.

### **References**

- [1] Douglas G. W. Price regulation and optimal service standards: the taxicab industry [J]. Journal of Transport Economics and Policy, 1972, 20:116-127.
- [2] Zhonggeng Han Mathematical modeling method and its application[M]. Beijing: Higher Education Press, 2005.6.